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A comparative study on the effect of microclimate on planting date and water requirements under different nitrogen sources on coriander (*Coriandrum sativum*, L.)

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Essential oil and oil yield

Abstract Evidences stated that microclimate causes noticeable effects on life cycle, consumptive use of water and planting time of the plant species. So, two field experiments were established at Sakha Agricultural Research Station during 2013 and 2014 growing seasons in order to evaluate the effect of microclimate on planting date as well as the influence of applying nitrogen fertilization (F_1: without nitrogen, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea + 30 kg N as compost/fed and F_4: 60 kg nitrogen/fed as urea) on growth, yield and components of coriander (*Coriandrum sativum*, L.) plants. The planting dates were October 10th, November 9th and December 9th. The obtained results showed that the microclimate affected planting date in the studied region which indicated that planting in the first third of December improved plant traits as significantly produced the heaviest weight of 1000 seeds, fruit yield/plant and /fed (1923.77 kg/fed) and decreased number of days from planting to harvest to 135 day, highest essential oil%, essential oil yield/plant and /fed, the highest N, P and K% for the two seasons. Cultivation on November 10th and December 10th were saving 11.25% and 25.17% of water applied, respectively as comparing with cultivation on October 9th. The highest productivity of irrigation water and water productivity were recorded on December 10th as 1.21 and 1.24 kg m^{-3}, respectively. On the other hand, the consumptive use decreased from 42.71 cm on October 9th to 31.74 cm on December 10th. For the application of nitrogen sources, the F_4 treatment was observed to produce the highest promoted effect on most growth parameters, yield, and the rate of increase in yield% reached to 46.25, essential oil% and oil yield in both seasons. Fourteen components were identified in coriander oil. Linalool was

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found to be the first major compound with the highest percentage obtained in oil sample for plants sown under all planting dates with all fertilization treatments. The highest percentage of linalool was obtained from oil sample from plants sowing on December 9th and fertilized with F_4 (60 kg nitrogen/fed as urea (89.41%).

Introduction

Coriander (*Coriandrum sativum* L.), an annual herbaceous plant of Apiaceae family, is one of the important seed spices occupying a prime position throughout the globe to add taste, flavor and pungency in various food items. Moreover, it is a frequent ingredient in the preparation of ayurvedic medicines and is a traditional home therapy for different ailments viz., rheumatism, joint pain, gastrointestinal complaints, flatulence (Said *et al.*, 1996), indigestion, insomnia, convulsions, anxiety, loss of appetite (Emamghoreishi *et al.*, 2005), etc. Coriander is a tropical crop and generally sown in the winter season for seed production.

Time of sowing is crucial for crop for the vegetative growth and ultimate expressions of yield. Any early or late sowing may hamper the growth, yield as well as quality of the crop. Time of planting controls the crop phenological development along with efficient conversion of biomass into economic yield (Khichar and Niwas, 2006). In case of coriander, early sowing leads to early flowering but may be vulnerable to damage in case of extreme cold and frost. On the other hand late sowing affected the growth as well as yield and quality in an adverse way. Meena and Malhotra (2006) reported that early sowing and selection of less susceptible variety proved a suitable component for the management of aphid on coriander.

Agriculture is strongly dependent on water resources and climatic conditions, particularly in regions of the world that are particularly sensitive to climatic hazards, such as Africa, South and Central America and Asia. Agriculture is a complex sector involving different driving parameters (environmental, economic, and social). It is now well recognized that crop production is very sensitive to climate change (McCarthy *et al.*, 2001). Decade-to-decade fluctuations in weather cause large variations in crop yields. Uncertainty in weather creates a risky environment for agricultural production. During the last decades the study of climate change effect in agricultural research has increased considerably. Globally, the 1990s was the warmest decade in the instrumental record (1861–2001), with the three warmest occurring 1998–2001. The increase in surface temperature over the 20th century is likely to have been greater than that for any other century in the last thousand years, with much of it being attributable to human activities (Houghton *et al.*, 2001).

Water is an important environmental factor affecting the growth of the crops particularly in arid and semi-arid regions such as Egypt; so, its optimum use for the production of the crops is vital. Moniruzzaman *et al.* (2013) showed that the water requirement of the crop depends much on the climatic and soil conditions. Nonjudicious irrigation was brought not only reduction of the efficiency of water and fertilizer use but also the reduction of the yield of the crop. Tripathi *et al.* (2009) on coriander showed that irrigation at 20, 40 and 60 days after sowing (3 irrigation) maintained higher umbel/plant, 1000 seed weight, production efficiency, nutrient use and N, P, K and S uptake. Maximum seed yield (1.96 ton/ha), was also recorded under 3 irrigations, which resulted in 38.31% and 3.93% increase in seed yield over 2 (20 and 40 DAS) and 4 (20, 40, 60 and 80 DAS) irrigation respectively. The application of 100% recommended dose of fertilizer registered significantly higher yield attributes, water use efficiency, production efficiency, N, P, K and S uptake and 20.65% and 12.04% increase in seed yield over 50% and 75% recommended dose of fertilizer respectively. Taheri *et al.* (2009) showed that the impact of water deficit stress was significant on the number of leaves, leaf dry weight and root length of chicory. Moreover, water deficit stress significantly declined biological yield of chicory. Aliabadi *et al.* (2008) studied the effect of two irrigation levels on coriander (*C. sativum* L.), including the irrigation after 30 and 60 mm evaporation from pan and concluded that low irrigation increased WUE and the highest WUE (on the average, 0.45 kg m^{-3}) was obtained under water deficit stress. Water stress in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration (Sarker *et al.*, 2005).

Application of fertilizer has been documented to enhance plant growth and development. Particularly nitrogen (N) is one of the greatest production inputs. Nitrogen is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds that regulate photosynthesis and plant production. Comparisons between inorganic and organic fertilizer-N sources are hard to perform since there is usually a dramatic difference in N availability from these two sources of N. Comparisons on the basis of similar amounts of total N applied are therefore of limited relevance to agricultural practice, whereas comparisons on the basis of similar N availability are hindered by the lack of reliable nitrogen release estimates for organic fertilizer sources derived from animal manures (Van Kessel and Reeves, 2002). Organic fertilizers in comparison with the chemical one have lower nutrient content and are slow to release but they are as effective as chemical fertilizers over longer periods of use (Sharafzadeh and Ordookhani, 2011). The compost must be added to conventional NPK fertilizer to improve soil structure, make the soil easier to cultivate, encourage root development, provide with nutrients and enable their increased uptake by plants. Moreover, compost aids water absorption and retention by the soil, reduces erosion and run-off and thereby protects surface waters from sedimentation, helps binding agricultural chemicals, keeps them out of water ways and protects ground water from contamination (LeaMaster *et al.*, 1998).

Egypt had a more different environmental condition in the last seasons. For this reason, the goals of our study were two-fold. First, the general aim was to help the decision maker to get the favorable planting date to meeting the future needs of coriander (*C. sativum*, L.) under the effect of microclimate of Kafr El-Sheikh Governorate and adopt the alternative options of irrigation and fertilizers management. Second, the specific aim was studying the effect of mineral and organic nitrogen fertilization on growth, yield and oil constituents of coriander plants under different planting dates.

Materials and methods

This investigation was conducted at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate. The site is located at Sakha 31°-07′N Latitude, 30°-57′E Longitude, N. elevation 6 m above mean sea level. This location is a representative of conditions in the middle Northern Part of Nile Delta region during the two successive growth seasons of 2013 and 2014 to study the effect of microclimate on planting date and water requirements under different nitrogen sources on growth, yield, oil yield and components of coriander (*C. sativum*, L.) plants. Seeds of coriander were local variety imported from Yemen state, and large-sized seeds and early flowering were sown in the field on three planting dates October 10th, November 9th and December 9th of the two seasons. The seeds were planted in hills at 25 cm distance on rows 60 cm apart in plots of (7.2 × 7.5 m) 54 m^2.

The physical and chemical properties of the experimental soil were determined before cultivation as shown in Table 1. Soil samples were analyzed in the Central Laboratory for Soil, Water and Plant Studies in Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC). Soil samples were taken from the experimental site at three depths: 0–20, 20–40 and 40–60 cm, to determine physical and chemical characteristics of the soil before cultivation. Bulk density, field capacity and permanent wilting point were determined according to Klute (1986). Available water was calculated as a difference between field capacity and permanent wilting point, soil pH was measured in soil water suspension, and total soluble salts were measured in saturated soil paste extract. Soluble cations and anions were determined in soil paste extract 1:2.5 (Jackson, 1973).

Meteorological conditions

Meteorological conditions during the two experimental growing seasons 2012/2013 and 2013/2014 for Sakha area are presented in Table 2.

The experimental design was split plot design, with four replications. The treatments were as follows:

A. *Three planting dates:* i.e. October 10th, November 9th, December 9th.
B. *Four nitrogen fertilization sources were as follows:*
   F_1 – Without nitrogen fertilization depending on the soil nitrogen.
   F_2 – Application of 60 kg nitrogen/fed as compost.
   F_3 – Application of 30 kg nitrogen/fed as urea 46.5% N + 30 kg N as compost/fed.
   F_4 – Application of 60 kg nitrogen/fed as urea (46.5% N).

Mineral nitrogen fertilizer was applied in two equal doses with the first and second irrigation. Phosphorus fertilization was applied at rate of 30 kg P_2O_5/fed as single calcium super phosphate 15.5% P_2O_5 in one dose during soil preparation. Potassium fertilizer was applied at the rate of 24 kg K_2O/fed as potassium sulfate (48% K_2O) (phosphorus and potassium fertilizer were added for all treatments). Compost was applied in one dose and mixed with soil before the planting.

Table 1 Mean physical and chemical analysis of the experimental soil before planting.

Soil depth (cm)	Particle size distribution (%)			Texture class	Bulk density (kg m^{-3})	F.C. (%, wt/wt)	P.W.P. (%, wt/wt)	A.W. (%, wt/wt)
	Sand	Silt	Clay					
Soil physical properties								
0–20	20.28	33.40	46.32	Clayey	1.17	45.30	23.70	21.60
20–40	19.36	28.35	52.29	Clayey	1.15	41.00	23.90	17.10
40–60	18.30	29.50	52.20	Clayey	1.24	38.90	22.60	16.30
Mean	19.31	30.42	50.27	Clayey	1.87	41.73	23.40	18.33

Soil depth (cm)	pH	EC (dS m^{-1})	Soluble cations (meq l^{-1})				Soluble anions (meq l^{-1})				Available N, P and K (ppm)			Organic matter (%)
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	N	P	K	
Soil chemical properties														
0–20	8.15	1.92	4.07	2.24	12.76	0.17	0.0	5.48	8.97	4.79	1.87	4.08	2.25	1.68
20–40	7.92	1.88	4.03	2.19	12.59	0.17	0.0	5.04	8.79	5.15	1.83	4.04	2.20	1.59
40–60	7.80	1.72	3.65	2.01	11.40	0.16	0.0	5.01	7.96	4.25	1.66	3.67	2.00	1.53
Mean	7.95	1.84	3.92	2.14	12.25	0.17	0.0	5.17	8.57	4.73	1.78	3.93	2.15	1.60

FC = field capacity, PWP = permanent wilting point, AW = available soil water.

Table 2 Mean of some meteorological data at Kafr El-Sheikh area during the two growing seasons of 2012/2013 and 2013/2014. *Source:* Meteorological station at Sakha 31°-07′N Latitude, 30°-57′E Longitude, N. elevation 6 m.

Months	T (°C)			RH (%)			U_2 (m/s)	Pan evap. (mm/day)	Rain (mm)
	Max.	Min.	Mean	Max.	Min.	Mean			
2012/2013									
Oct. 2012	29.92	20.64	25.28	85.24	55.30	70.27	0.86	4.30	6.57
Nov. 2012	25.32	15.47	20.40	89.53	61.80	75.67	0.66	1.87	28.20
Dec. 2012	21.35	10.52	15.94	84.77	60.83	72.80	0.73	2.55	13.02
Jun. 2013	19.22	7.62	13.42	91.06	65.35	78.21	0.52	1.99	78.74
Feb. 2013	20.68	8.88	14.78	89.89	64.04	76.97	0.73	2.89	–
Mar. 2013	24.56	12.45	18.51	79.48	50.84	65.16	1.03	4.46	–
Apr. 2013	26.04	15.87	20.96	74.20	43.90	59.05	1.11	5.30	8.40
2013/2014									
Oct. 2013	27.79	19.42	23.61	76.23	57.36	66.80	1.26	2.87	–
Nov. 2013	25.39	15.14	20.27	87.00	64.43	75.72	0.80	2.28	–
Dec. 2013	19.64	8.51	14.06	92.07	67.61	79.84	0.61	4.15	81.9
Jun. 2014	20.34	7.55	13.95	93.69	70.55	80.55	0.54	1.60	20.7
Feb. 2014	20.64	8.19	14.42	91.90	67.15	79.53	0.79	2.52	16.5
Mar. 2014	22.94	11.71	17.33	86.10	56.80	71.45	0.96	3.14	26.2
Apr. 2014	27.50	15.53	21.52	81.80	49.80	65.8	1.07	4.91	20.2

Table 3 Chemical and biological characters of compost.

Characters	Value	Characters	Value
pH	7.1	Available nitrogen (mg/kg)	88
EC (dS m^{-1} at 25 °C)	5	Available P (mg/kg)	23
C/N ratio	18:1	Available K (mg/kg)	120
Organic matter (%)	21.78	Density (g/cm^3)	0.7
Total nitrogen (%)	1.21	Nematoda	0.0
Total P (%)	0.30	Pathogen	0.0
Total K (%)	0.80	Saturation percentage (sp)%	110

Chemical composition of the used compost is shown in Table 3.

Irrigation data collection

Irrigation water applied

Irrigation water was controlled and measured by flow rates from orifice discharging is the orifice meter and water was distributed and maintained by spills inserted beneath the bank of each irrigated furrows set. Applied irrigation water quantity was determined according to Michael (1978) as follows:

$$Q = CA\sqrt{2gh}$$

where

Q = water discharge, $cm^3\ s^{-1}$,
C = coefficient of discharge ranged from 0.6 up to 0.8 or more,
A = weir cross-sectional area, cm^2,
g = acceleration due to of gravity, 981 cm s^{-2}, and
h = pressure head causing water discharge, cm.

Productivity of irrigation water (PIW, kg m^{-3})

Productivity of irrigation water (PIW) was calculated according to Ali *et al.* (2007):

$$\text{PIW} = Y/I$$

where

PIW = productivity of irrigation water, kg m^{-3},
Y = fruit yield, kg fed^{-1}, and
I = irrigation water applied, $m^3\ \text{fed}^{-1}$.

Water consumptive use

Soil moisture percentage was determined (on weight basis) just before and 48 h after each irrigation as well as at harvest to compute the actual consumed water as stated by Hansen *et al.* (1979) as follows:

$$\text{CU} = \text{S.M.D.} = \sum_{i=1}^{i=4} \frac{\phi_2 - \phi_1}{100} \times D_{bi} \times D_i$$

where

CU = water consumptive use (cm) in the effective root zone of 60 cm soil depth,
S.M.D. = soil moisture depletion, cm,
i = number of soil layer (1–3),
D_i = soil layer thickness (20 cm),
D_{bi} = bulk density (kg m^{-3}) of the concerned soil layer,
ϕ_1 = soil moisture percentage (wt/wt) before irrigation, and
ϕ_2 = soil moisture percentage (wt/wt), 48 h after irrigation.

Consumptive use efficiency (Ecu)

The consumptive use efficiency (Ecu) was calculated as described by Doornbos and Pruit (1975) as follows:

$$\mathrm{Ecu} = \frac{\mathrm{ETc}}{\mathrm{WA}} \times 100$$

where

Ecu = consumptive use efficiency%,
ETc = total evapotranspiration $\simeq$ consumptive use, $m^3\ fed^{-1}$,
WA = water applied to the field, $m^3\ fed^{-1}$.

Water productivity (WP, kg m^{-3})

Water productivity is generally defined as crop yield per cubic meter of water consumption. Water productivity can be also defined as crop production per unit amount of water used (Molden, 1997). Concept of water productivity in agricultural production system is focused on producing more food with the same water resources or, producing the same amount of food with less water resources. Water productivity was calculated according to Ali *et al.* (2007):

$$\mathrm{WP} = Y/\mathrm{ET}$$

where

WP = water productivity, kg m^{-3},
Y = fruit yield, kg fed^{-1},
ET = total water consumption of the growing season, $m^3\ fed^{-1}$.

Coriander plant data collection

Coriander plants were harvested on 1st, 11th and 19th April for the first, second and third planting dates, respectively in both seasons. The following data were recorded per plant:

A. *Vegetative growth characters:*
1. Plant height (cm).
2. Number of branches/plant.
3. Fresh and dry weight (g/plant).

B. *Flowering and yield characters:*
1. Number of days from plating to flowering (NDP) and to harvest (NDH).
2. Number of umbels per plant.
3. Weight of 1000 seeds (g).
4. Fruit yield per plant (g).
5. Fruit yield per fed (kg).
6. Rate of increase in yield% = treatment – control/control * 100.

C. *Chemical analysis:*

Minerals including, nitrogen percentage using Kjeldahl method were described by Hach *et al.* (1985), phosphorus percentage was estimated according to A.O.A.C. (1970) and potassium percentage was determined by flame photometer using the method described by Brown and Lilleland (1946).

D. *Essential oil:*

Oil percentage of the fruits was determined according to British Pharmacopoeia (1963), and essential oil yield/plant (ml) and /fed (l) was calculated by multiplying oil (%) by coriander fruits yield. GC/Mass analysis of volatile oil of each treatment was performed with specification of the apparatus used according to Robert (1995).

Data of both seasons were tabulated and statistically analyzed according to procedure described by Steel and Torrie (1980) and differences between the means were compared by Duncan's Multiple Range Test (Snedecor and Cochran, 1980) using COSTAT computer program.

Results and discussion

Effect of microclimate on planting date, water applied and water productivity

Number of days from planting to flowering (NDF) and number of days to harvest (NDH)

Data in Fig. 1 referred that there was influenced on number of days to flowering (NDF) by microclimate (Table 2) under the region study at different planting dates as there was a correlation between NDF and accumulation temperature. Irrespective to different of planting dates the coriander plants were flowering after consuming about 120 AT °C (118.8, 119.9 and 117.4 AT °C) and about 110 AT °C (110, 113 and 112.7) accumulation temperature for October 10th, November 9th and December 9th, respectively in both seasons. On the other hand, the percentage of number of days to flowering (NDF) increased to 29%, 47% and 59% for plants sowing during October 10th, November 9th and December 9th, respectively in both seasons. Furthermore, AT C° was occurred during the initial period of plant growth after 50, 71 and 76 days for plants sowing during October 10th, November 9th and December 9th, respectively in both seasons. The present findings are in parallel with those of Iglesias (2006) who found that the primary variable influencing phasic development rate is temperature. Regulation of seed number depends on supplying adequate nutrition and environmental conditions in a stage that plant enters reproductive phase from vegetative phase and subsequent stage. Similarly, Ehteramyan (2003) on black cumin reported that delaying sowing date was better because of the possible occurrence of sudden winter chilling as mentioned by Rashed (2012) on *Melissa officinalis*, L.

Data in Fig. 2 show that the plants sown during October 10th were harvested after 170 days and decreased to 150 and 129 days for November 9th and December 9th, respectively. Planting in October 10th recorded the highest values of accumulation temperature °C (AT °C) from planting to harvest as 269.7 and 261.0 AT °C in the two seasons, respectively and decreased by 10.9% and 10.2% with few differences for plants sown during November 9th and December 9th, respectively.

On water applied and water productivity

Water applied ($m^3\ fed^{-1}$)

Table 4 shows the seasonal values of water applied (WA) which consists of two components, irrigation water and rainfall. Seasonal rainfall was 525.0, 475.0 and 378.5 $m^3\ fed^{-1}$ during first growing season and 610.3, 610.3 and 554.4 $m^3\ fed^{-1}$ during second growing season for planting date October 10th, November 9th and December 9th, respectively for coriander crop. Under the two seasons, the highest water applied

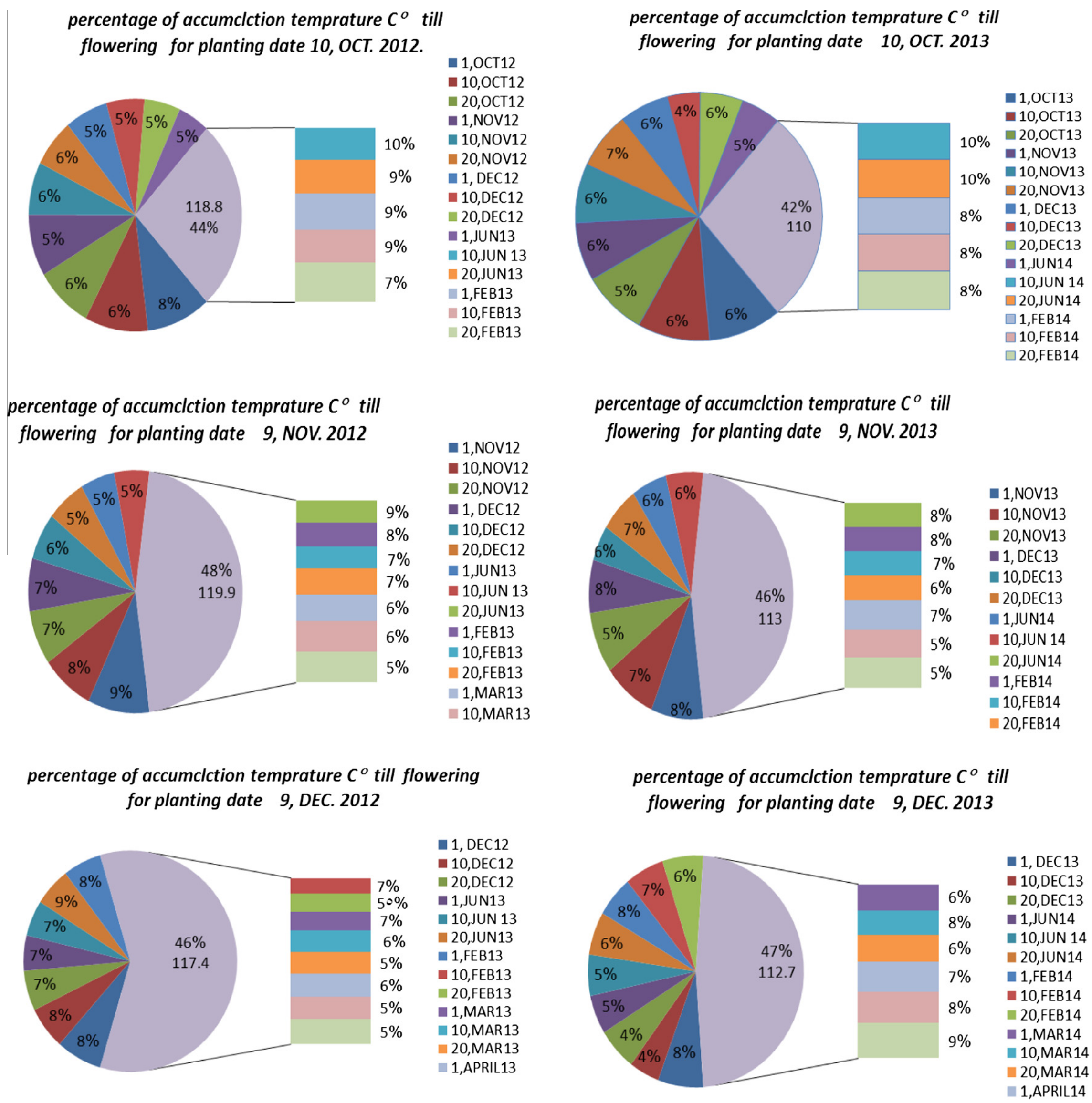

Fig. 1 Percentage of accumulation temperature °C till flowering in the three planting dates in the two seasons 2013 and 2014.

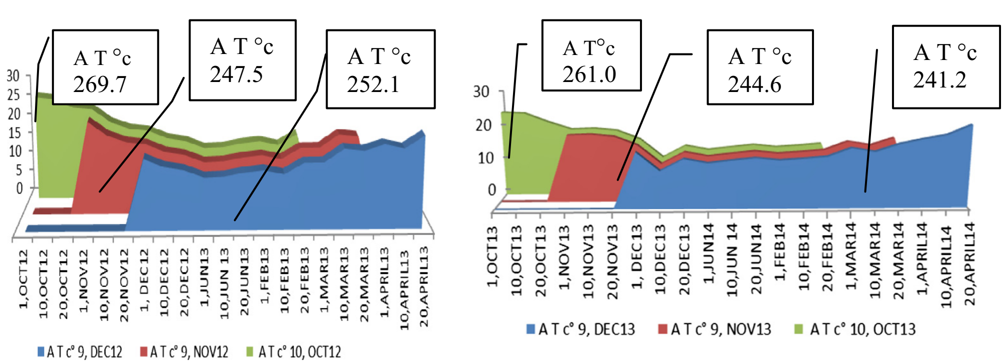

Fig. 2 Accumulation temperature °C from planting to harvesting in the three planting dates in the two seasons 2013 and 2014.

Table 4 Seasonal water applied m^3 fed^{-1}, cm and productivity of irrigation water PIW, kg m^{-3}.

Planting dates	Irrigation parameters[a]								
	WA (m^3 fed^{-1})			WA (cm)			PIW (kg m^{-3})		
	2012/2013	2013/2014	Overall mean	2012/2013	2013/2014	Overall mean	2012/2013	2013/2014	Overall mean
10^{th} October	1965.0	1990.5	1977.75	46.79	47.39	47.09	0.654	0.739	0.697
9^{th} November	1725.0	1785.3	1755.15	41.07	42.51	41.79	0.904	0.939	0.922
9^{th} December	1451.0	1509.0	1480.0	34.55	35.93	35.24	1.145	1.275	1.21

[a] Water applied (WA) and productivity of irrigation water (PIW).

values 46.79 cm (1965 m^3 fed^{-1}) and 47.39 cm (1990.5 m^3 fed^{-1}) were recorded for October 10^{th} planting date in the first and second seasons, respectively, while, the lowest values were recoded under December, 9^{th} in the two growing seasons. The water savings when compared with irrigation for October 10^{th} were 12.21% and 10.31% decrease in IW in the first and second seasons, respectively for November, 9^{th}, and 26.16% and 24.19% decrease in WA in the first and second seasons, respectively for December, 9^{th}, higher than irrigation for October 10^{th}. This decrease in WA in the second and third planting date is because of decrease in growing season with 20 and 41 days for November 9^{th} and December 9^{th} respectively.

Productivity of irrigation water (PIW, kg m^{-3})

In agriculture, productivity or efficiency is the relationship between output and input calculated as a ratio (output/input) or as the slope of the functional relationship (Δ output/Δ input). In this study the last planting date (December 9^{th}) recorded the highest PIW with values 1.145 and 1.275 kg m^{-3} in the first and second seasons, respectively with increase with 42.88% and 42.04% compared with the first planting date and increase with 21.05% and 26.35% compared with the second planting date.

Consumptive use (cm)

Consumptive water use is water removed from available supplies without return to a water resource. Seasonal CU for coriander clearly was affected by both planting date and nitrogen application treatments in the two growing seasons. Concerning with the effect of planting date treatments, the highest values were recorded under planting date (October 10^{th}) comparing with the other treatments the second and third one, the highest mean value 42.11 cm was recorded by planting date (October 10^{th}), and lowest 31.74 cm was recorded by December 9^{th}, Table 5. Increasing value of consumptive use for treatment (October 10^{th}) which received high number of irrigations in comparison with other treatments was due to increasing amount of applied water which resulted in increasing soil moisture content.

On the other hand, the nitrogen source effect on CU showed the most efficient application of nitrogen as urea under

Table 5 Consumptive use (cm), consumptive use efficiency (Ecu) and water productivity (WP, kg m^{-3}).

Planting dates		Irrigation parameters[a]								
		CU (cm)			Ecu (%)			WP (kg m^{-3})		
		2012/2013	2013/2014	Overall mean	2012/2013	2013/2014	Overall mean	2012/2013	2013/2014	Overall mean
10^{th} October	F_1	40.90	41.10	41.00	87.42	86.72	87.22	0.725	0.853	0.789
	F_2	42.15	42.00	42.08	90.06	88.62	89.34	0.726	0.834	0.780
	F_3	42.50	42.40	42.60	90.83	89.46	90.15	0.720	0.826	0.773
	F_4	42.90	43.00	42.95	91.69	90.73	91.21	0.713	0.815	0.764
Mean		42.11	42.13	42.11	90.00	88.88	89.48	0.721	0.832	0.776
9^{th} November	F_1	36.17	36.78	36.48	88.06	86.52	87.29	0.783	0.770	0.777
	F_2	36.70	37.20	36.95	89.35	87.51	88.43	0.913	0.900	0.907
	F_3	37.10	38.30	37.70	90.33	90.10	90.21	1.075	1.039	1.057
	F_4	38.00	39.00	38.50	92.52	91.75	92.13	1.090	1.062	1.077
Mean		36.99	37.82	37.41	90.06	88.97	89.52	0.965	0.943	0.955
9^{th} December	F_1	30.00	31.30	30.65	86.83	87.11	86.97	0.944	0.905	0.925
	F_2	30.80	32.10	31.45	89.15	89.34	89.25	1.087	1.043	1.065
	F_3	31.60	32.90	32.25	91.46	91.57	91.51	1.260	1.210	1.235
	F_4	32.20	33.00	32.60	93.20	91.84	92.52	1.286	1.255	1.271
Mean		31.15	32.33	31.74	90.16	89.97	90.06	1.144	1.103	1.124

[a] Consumptive use (CU), consumptive use efficiency (Ecu) and water productivity (WP).

all planting dates with overall mean values 42.95, 38.50 and 32.60 cm for October 10th, November 9th and December 9th respectively. Nitrogen deficit reduces yield per unit evapotranspiration by potentially affecting all components, i.e. biomass per unit transpiration. Firstly, nitrogen deficiency reduces photosynthesis; hence, biomass per unit transpiration is reduce compiled the response of biomass per unit transpiration to nitrogen supply for all major crop species.

Consumptive use efficiency (Ecu, %)

Consumptive use efficiency (Ecu) is a parameter which indicates the capability of plants to utilize the soil moisture stored in the effective roots zone. Percentage of Ecu shown in Table 5 cleared that the highest overall mean value 90.06% was obtained on 9th December. Therefore, by decreasing the applied water, higher amount of irrigation water could be beneficially used by the growing plants which resulted in decreasing water losses.

Water productivity (WP, kg m^{-3})

Water productivity is an important physiological characteristic that is related to the ability of crop to cope with water stress. WP can be defined as biomass produced per unit area per unit water evapotranspired. Data in Table 5 show that the value of WP was increased under increasing water stress conditions. The highest values were recorded on December 10th in the two growing seasons. These results are in agreement with Aliabadi *et al.* (2008) who found that coriander low irrigation increased WUE, and the highest WUE was obtained under water deficit stress. For the nitrogen source effect on PW showed the same trend in CU. These results are harmony with Tetarwal and Rana (2006) and reported that the highest water use efficiency, consumptive use and rate of moisture use were recorded with 80 kg N/ha, followed by 40 kg N/ha and the control. It might be due to the fact that increase in equivalent yield was more than the corresponding increase in consumptive use of water due to fertility level. The increased activity, growth and proliferation of root system due to greater translocation of photosynthates to roots owing to balanced nutrition might have resulted in extraction of more moisture from deeper soil profile.

Effect of planting dates and nitrogen fertilization on

Vegetative growth characters

Plant height, number of branches/plant, and fresh and dry weight

A perusal of data in Table 6 indicated that the latest planting date of coriander plants December 9th caused a reduction in plant height, number of branches/plant, and fresh and dry

Table 6 Effect of planting date, mineral and organic nitrogen fertilization on plant height (cm), number of branches, fresh weight (g) and dry weight (g) of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

Planting date	Fertilization treatments	Plant height (cm)		Number of branches/plant		Fresh weight (g)		Dry weight (g)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10th October	F_1	124.88	130.67	8.88	9.88	360.55	398.88	159.22	188.77
	F_2	123.33	129.00	10.22	10.22	377.22	438.33	122.89	146.00
	F_3	120.33	124.44	9.22	10.77	398.33	438.88	169.11	184.88
	F_4	131.22	134.22	10.44	11.88	391.11	494.44	139.22	177.11
9th November	F_1	127.44	135.78	8.22	9.22	355.00	408.88	161.11	182.77
	F_2	125.77	140.11	9.44	8.66	419.00	495.00	156.66	155.55
	F_3	133.00	135.22	8.55	8.66	521.0	565.00	216.66	230.00
	F_4	133.66	143.22	9.66	11.77	488.44	613.33	286.11	246.66
9th December	F_1	113.66	130.22	6.77	6.00	521.11	592.22	204.44	255.00
	F_2	120.22	133.88	6.44	6.55	503.88	569.44	299.44	343.88
	F_3	124.11	139.44	7.88	7.22	679.44	796.33	281.11	368.33
	F_4	124.77	137.67	6.22	6.33	722.22	860.00	256.11	439.44
$LSD_{0.05}$		3.554^{**}	3.979^{***}	0.584^{***}	0.808^{***}	13.85^{***}	23.32^{***}	13.71^{***}	14.13^{***}
Planting date	10 Oct.	129.97	138.58	9.69	10.69	606.66	704.5	285.27	351.66
	9 Nov.	124.94	135.30	8.97	9.55	446.00	520.55	180.14	203.75
	9 Dec.	120.69	129.58	6.83	6.30	381.85	442.63	147.61	174.19
$LSD_{0.05}$		5.098^{*}	2.011^{***}	0.308^{**}	0.413^{***}	4.82^{***}	22.39^{***}	17.55^{***}	6.36^{***}
Fertilization treatment	F_1	122.00	132.22	7.96	8.37	412.22	466.66	174.92	208.85
	F_2	123.11	134.33	8.70	8.18	433.52	500.92	193.00	215.14
	F_3	125.81	133.03	8.55	8.85	532.96	600.07	222.29	261.07
	F_4	129.88	138.37	8.77	10.00	533.92	655.92	227.14	287.74
$LSD_{0.05}$		2.593^{***}	1.512^{***}	0.437^{***}	0.379^{***}	9.63^{***}	10.32^{***}	11.25^{***}	7.11^{***}

*, **, *** and NS: significant at $p \leqslant 0.05$, 0.01, 0.001 or not significant, respectively. Means separated at $p \leqslant 0.05$, LSD test.
F_1: without nitrogen fertilization, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea (46.5% N) + 30 kg N as compost/fed, F_4: 60 kg nitrogen/fed as urea (46.5% N).

weight/plant as compared with planting at 10th October in both seasons. This time 10th October had an obvious effect on giving the highest significant values of all traits in both seasons. These results may be due to the fact that the early planting increased the coriander production potential by extending the vegetative growth period and increased the total length of time that the coriander needs in the field to be exposed to the different environments and the promotion response of some growth criteria by various planting dates may be attributed to the prevailing favorable day length and temperature conditions, which produced better growth as shown in Table 2 and Fig. 1. Similarly Sharangi and Roychowdhury (2014) on coriander showed that a delay in sowing dates from October to December decreased plant height and number of main branches. Ehteramyan *et al.* (2007) on cumin showed that the different fall sowing dates of cumin had significant influences on height of plants. Meanwhile, the early planting date enhanced the growth characters for various plants. In this connections Naguib *et al.* (2007) on *Ruta graveolens* L. showed that seeds planted on 1st of October, produced significantly the tallest plants, more branches and the heaviest weight of leaves and stems compared to those planted on the 1st of November. Sadeghi *et al.* (2009) on cumin revealed that early sowing date resulted in taller plants.

Application of various N fertilization treatments caused pronounced increments in plant height, number of branches/plant, and fresh and dry weight/plant in both seasons over untreated plants F_1. Generally, F_4 of 60 kg mineral nitrogen as urea was observed to be the most favorable for the highest records of plant height, number of branches/plant, and fresh and dry weight/plant since it produced the highest promotion effect in all cases for both seasons. These results may be attributed to the fact that nitrogen is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds that regulate photosynthesis and plant production. This was in line with the observation of Rastgou *et al.* (2013) on safflower.

Data of the interaction between N fertilization treatments and planting date showed that planting in November 9th and fertilized with F_4 caused pronounced increments in plant height in the two seasons. While, planting in October 10th with the same fertilized treatment recorded the highest number of branches/plant in the two seasons and the highest fresh and dry weight/plant recorded from planting in December 9th with the same fertilized treatment F_4 in the two seasons. These results may be attributed to environmental factors that have an important role on plant growth and essential oil in medicinal plants which are affected by some nutrimental elements (Ahmadian *et al.*, 2011).

Relationship between planting date and nitrogen fertilization with some vegetative parameters (plant height, number of branches, fresh weight and dry weight)

A positive linear relationship was obtained between planting date with plant height, number of branches, and fresh and dry weight (Fig. 3). They are highly significant (with correlation coefficient values, r = 0.97, 0.92, 0.94 and 0.87 respectively for the first season and 0.99, 0.92, 0.94 and 0.91 respectively for the second season). The positive relationship indicated that each of plant height, number of branches, fresh weight and dry weight decreased under lasting plant date December 9th and increased under first planting date October 10th. Similarly, a positive linear relationship was obtained between nitrogen fertilization with plant height, number of branches, and fresh and dry weight (Fig. 3). They are highly significant (with correlation coefficient values, r = 0.65, 0.77, 0.96 and 0.93 respectively for the first season and 0.94, 0.64, 0.86 and 0.94, respectively for the second season). The positive relationship indicated that each of plant height, number of branches, and fresh and dry weight increased with the use of F_4: 60 kg nitrogen/fed as urea.

Number of umbels per plant, weight of 1000 seeds (g), fruits yield per plant (g) and per fed (kg) and rate of increase in yield%

Data presented in Table 7 and Fig. 4 show the superior effect of the later planting dates November 9th on number of umbels/plant and December 9th on weight of 1000 seeds, fruits yield/plant and /fed and rate of increase in yield% in both seasons. These results may be due to the fact that the lesser temperature rise during the growing-season would have a good impact on production which increased production by saving 60 days in season and there was a significant positive relationship between biological yield and average minimum temperature during growth period as biological yield was increased by increasing average minimum temperature. On the other hand, there was a negative correlation between biological yield and rainfall in growth period as reported by Nezami *et al.* (2011) on cumin. Khah (2009) on coriander found that the 2nd and 3rd sowings had the largest 1000 seed weight (20.35, 19.65 g/plant, respectively).

Nitrogen fertilization progressively increased number of umbels/plant and weight of 1000 seeds, fruits yield/plant and /fed and rate of increase in yield% in both seasons over untreated plants. Moreover, F_4 (60 kg nitrogen/fed as urea) produced the maximum values of number of umbels/plant and weight of 1000 seeds, fruits yield/plant and /fed in both seasons and the rate of increase in yield% reached to 46.25 and 29.44 in the two seasons, respectively. These results may be due to the fact that N-fertilizers seem to give the strongest impulse to fresh and dry weight when applied in the faster available forms, and the application of N in organic form, on the contrary, generates much less evident effects; it is possible that the fertilizer units applied in this form show a delayed effect, since they need to undergo mineralization in order to release in the soil mineral nitrogen to be directly used by plants (Carrubba and Ascolillo, 2009) on coriander. In this respect Jamali and Martirosyan (2013) on coriander showed that nitrogen fertilizer had significant effect on seed weight, weight per plant, 1000 seed weight and plant height. The highest seed weight and 1000 seed weight were obtained from application of 90 kg/ha nitrogen.

Concerning to the interaction between planting dates and N fertilization treatments data recorded significantly increased number of umbels/plant, weight of 1000 seeds, fruits yield/ plant and /fed and rate of increase in yield% in both seasons. Coriander plants treated with F_4 (60 kg nitrogen/fed as urea) and sowing on November 9th recorded the highest number of umbels/plant and weight of 1000 seeds while the same treatment sowing on December 9th recorded the highest fruits yield/plant and /fed and the rate of increase in yield% reached to (75.83 and 60.36) in the two seasons, respectively. Similar were the results of Ehteramyan (2003) on black cumin and Ehteramyan *et al.* (2007) on cumin.

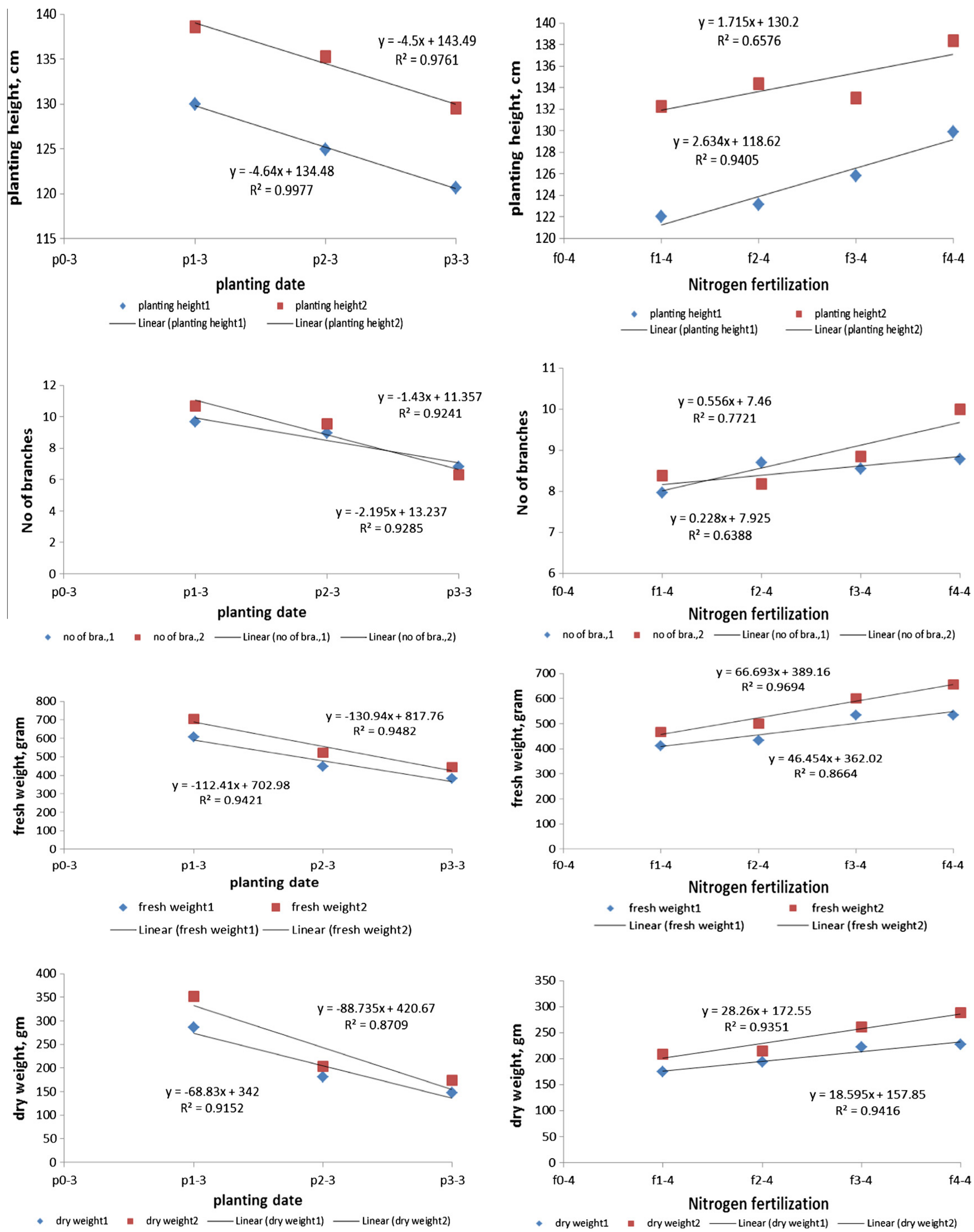

Fig. 3 Correlation between planting date and mineral and organic nitrogen fertilization on plant height (cm), number of branches, fresh weight (g) and dry weight (g) of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

Relationship between planting date and nitrogen fertilization with some vegetative parameters (number of umbels per plant, weight of 1000 seeds, fruits weight per plant (g) and fruits weight per fed)

A positive linear relationship was obtained between planting date with number of umbels per plant, weight of 1000 seeds, and fruits weight per plant and per fed (Fig. 4). They are highly significant (with correlation coefficient values, r = 0.04, 0.86, 0.93 and 0.99 respectively for the first season and 0.34, 0.80, 0.98 and 0.93 respectively for the second season). The positive relationship indicated that each of number of umbels per plant, weight of 1000 seeds, fruits weight per plant and per fed increased under the last planting date December 9th. Similarly, a positive linear relationship was obtained between nitrogen

Table 7 Effect of planting date, mineral and organic nitrogen fertilization on number of umbels per plant, weight of 1000 seeds (g), fruits yield per plant (g) and per fed (kg) and rate of increase in yield% of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

Planting date	Fertilization treatments	No. of umbels per plant		Weight of 1000 seeds (g)		Fruits yield per plant (g)		Fruits yield per fed (kg)		Rate of increase in yield%	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10th October	F_1	150.11	162.55	12.17	12.43	63.11	76.22	1262.22	1524.44	–	–
	F_2	149.33	172.22	12.60	12.66	52.33	62.77	1046.66	1255.55	−17.08	−17.64
	F_3	142.33	165.00	13.32	13.53	74.33	79.77	1486.66	1595.55	17.78	4.66
	F_4	160.44	176.33	14.10	14.16	67.22	75.55	1344.44	1511.11	6.51	−0.87
9th November	F_1	138.33	175.44	14.41	14.43	56.44	61.66	1128.88	1233.33	–	–
	F_2	150.00	175.33	13.75	14.07	72.22	98.88	1444.44	1591.11	27.95	29.00
	F_3	154.55	198.66	13.02	13.31	93.00	95.33	1860.00	1906.66	64.77	54.59
	F_4	184.88	235.00	15.88	16.17	90.22	98.88	1804.44	1977.77	59.84	60.36
9th December	F_1	123.00	154.88	12.91	13.56	58.83	67.22	1176.66	1552.22	–	–
	F_2	137.55	130.00	13.45	14.00	86.44	95.00	1728.88	1980.00	46.93	27.56
	F_3	142.66	178.44	15.98	15.56	83.44	89.44	1668.88	2072.88	41.83	33.54
	F_4	162.77	180.77	15.62	15.30	103.44	109.44	2068.88	2090.00	75.83	34.65
$LSD_{0.05}$		4.039***	6.965***	0.103***	0.138***	3.12***	4.016***	62.56***	327.89***		
Planting date	10 Oct.	150.55	169.02	13.05	13.20	64.25	73.58	1285.00	1471.66	–	–
	9 Nov.	156.94	196.11	14.26	14.50	77.92	83.86	1559.44	1677.22	21.36	13.97
	9 Dec.	141.50	161.02	14.49	14.60	83.04	90.27	1660.83	1923.77	29.25	30.72
$LSD_{0.05}$		3.105***	3.282***	0.056***	0.081***	1.70***	3.37***	34.04***	57.28***		
Fertilization treatment	F_1	137.14	164.26	13.16	13.47	59.46	68.37	1189.25	1436.66	–	–
	F_2	145.62	159.18	13.27	13.58	70.33	79.11	1406.66	1608.88	18.28	11.99
	F_3	146.52	180.70	14.11	14.13	83.33	88.18	1671.85	1858.37	40.58	29.35
	F_4	169.37	197.37	15.20	15.21	86.96	94.62	1739.25	1859.62	46.25	29.44
$LSD_{0.05}$		2.78***	3.79***	0.057***	0.057***	1.77***	1.89***	35.48***	123.34***		

*, **, *** and NS: significant at $p \leqslant 0.05$, 0.01, 0.001 or not significant, respectively. Means separated at $p \leqslant 0.05$, LSD test.

F_1: without nitrogen fertilization, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea (46.5% N) + 30 kg N as compost/fed, F_4: 60 kg nitrogen/fed as urea (46.5% N).

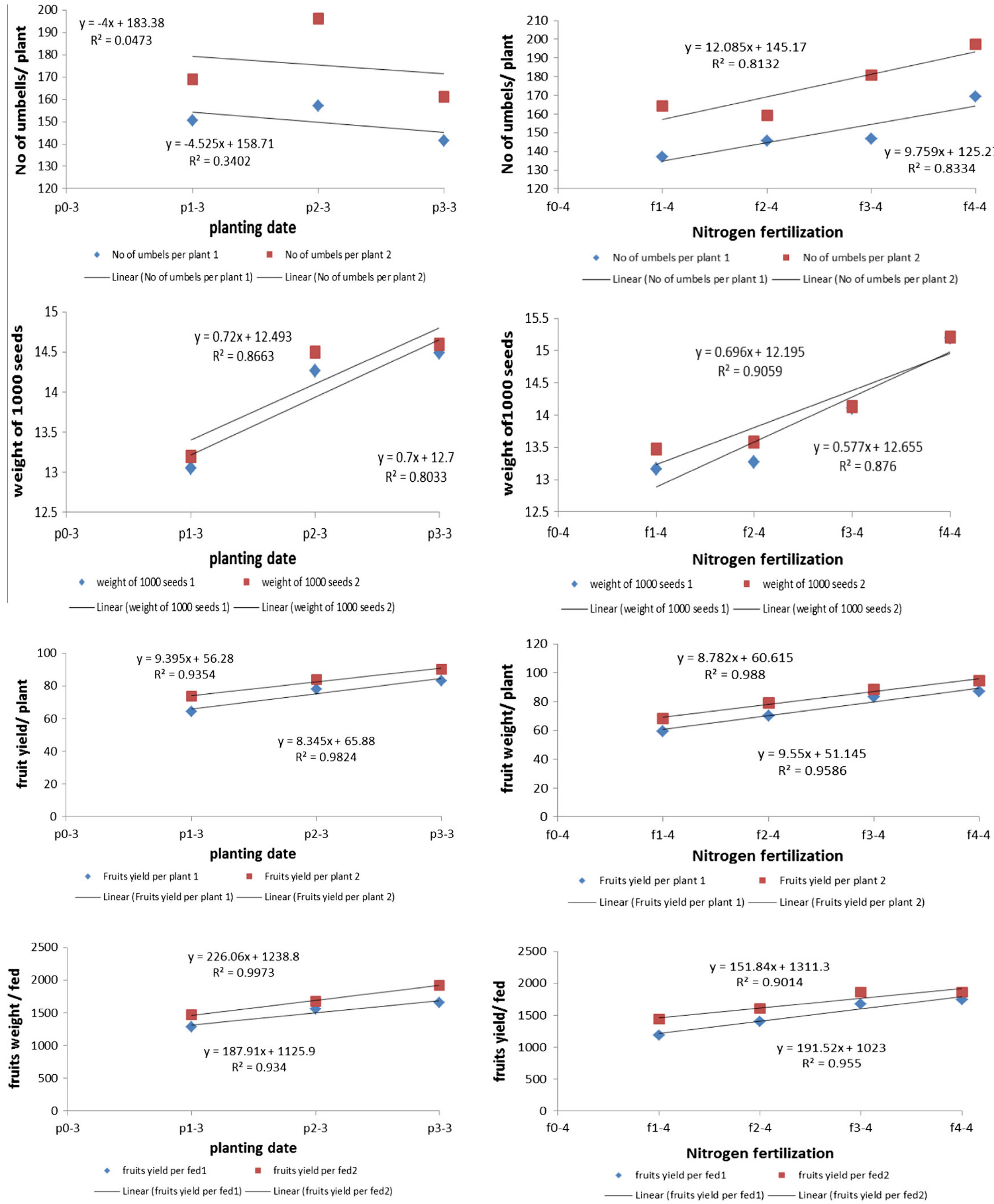

Fig. 4 Correlation between planting date and nitrogen fertilization on number of umbels per plant, weight of 1000 seeds, fruits weight per plant and per fed of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

fertilization with number of umbels per plant, weight of 1000 seeds, fruits weight per plant and per fed (Fig. 4). They are highly significant (with correlation coefficient values, $r = 0.81$, 0.90, 0.98 and 0.90 respectively for the first season and 0.83, 0.87, 0.95 and 0.95 respectively for the second season). The positive relationship indicated that each of number of umbels per plant, weight of 1000 seeds, fruits weight per plant and per fed increased with the use of F_4: 60 kg nitrogen/fed as urea.

Chemical analysis

N, P and K%

The results presented in Table 8 demonstrated that planting dates significantly affected on N, P and K% in the two seasons. Sowing plants on December 9th significantly increased N, P and K% over the earlier planting date in the two seasons. In this respect, Naguib *et al.* (2007) on *R. graveolens* L. showed that the uptake of nitrogen and phosphorus gave higher accu-

Table 8 Effect of planting date, mineral and organic nitrogen fertilization on N, P and K% of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

Planting date	Fertilization treatments	N%		P%		K%	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10th October	F_1	2.10	2.07	0.54	0.59	1.32	1.39
	F_2	2.40	2.45	0.47	0.52	2.41	2.76
	F_3	2.41	2.45	0.41	0.46	2.15	2.16
	F_4	2.33	2.32	0.48	0.59	2.59	2.63
9th November	F_1	2.22	2.19	0.28	0.31	2.73	2.73
	F_2	2.32	2.29	0.48	0.48	2.51	2.54
	F_3	2.14	2.13	0.53	0.54	3.08	3.10
	F_4	2.28	2.31	0.62	0.50	1.98	1.99
9th December	F_1	2.05	2.20	0.64	0.66	1.70	1.71
	F_2	2.12	2.13	0.49	0.53	1.26	1.51
	F_3	2.58	2.59	0.51	0.57	3.47	3.50
	F_4	2.37	2.38	0.53	0.58	3.92	3.96
$LSD_{0.05}$		0.054^{***}	0.059^{***}	0.026^{***}	0.028^{***}	0.037^{***}	0.050^{***}
Planting date	10 Oct.	2.25	2.28	0.47	0.54	2.12	2.23
	9 Nov.	2.25	2.23	0.47	0.46	2.58	2.59
	9 Dec.	2.28	2.32	0.54	0.58	2.59	2.67
$LSD_{0.05}$		0.012^{**}	0.027^{**}	0.334^{**}	0.021^{***}	0.023	0.046^{***}
Fertilization treatment	F_1	2.21	2.16	0.48	0.52	1.92	1.94
	F_2	2.28	2.29	0.48	0.51	2.06	2.27
	F_3	2.29	2.33	0.48	0.52	2.90	2.92
	F_4	2.33	2.34	0.54	0.55	2.83	2.86
$LSD_{0.05}$		0.028^{***}	0.038^{***}	0.019^{***}	0.017^{***}	0.0168^{***}	0.043^{***}

*, **, *** and NS: significant at $p \leqslant 0.05$, 0.01, 0.001 or not significant, respectively. Means separated at $p \leqslant 0.05$, LSD test.
F_1: without nitrogen fertilization, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea (46.5% N) + 30 kg N as compost/fed, F_4: 60 kg nitrogen/fed as urea (46.5% N).

mulation at second sowing date (November 1st). Mann and Vyas (1999) on *Plantago ovata* reported that N, P and K uptake by seed was significantly greater under the earliest sowing date November 1st for coriander and November 15th for Isabgol. Meanwhile, Lopez-Camelo *et al.* (1995) obtained non-significant differences in nutrient accumulation due to sowing date (May 27th or August 19th) of *C. sativum*.

The three N fertilization types applied to *C. sativum*, L. caused in general, an increment in the accumulation of the nutrients as presented in Table 8. The highest N and P% was recorded when plants were treated with F_3 (30 kg nitrogen/fed as urea), while plants treated with F_4 (60 kg nitrogen/fed as urea) recorded the highest K% in the two seasons. These results may be explained by their role on improving roots that lead to greater absorbing surface of root consequently increasing nutrients uptake and improving transpiration of the nutrients from the soil to plant organs via the roots (Najjar, 1985). Similarly, Singh and Ganesha Rao (2009) on patchouli revealed that application of 200 kg N/ha and 41.5 kg K/ha produced significantly higher N and K uptake.

Regarding the interaction between planting dates and the addition of N fertilization, the results indicated that in general, planting date combined with various fertilization treatments had a promoted effect on producing higher N, P and K%. Meanwhile, the highest mean values of N% resulted from F_3 (30 kg nitrogen/fed as urea + 30 kg N as compost/fed) planting on December 9th. While, the highest mean values of P% resulted from application of F_1 (60 kg nitrogen/fed as compost) and highly K% with the application of F_4 (60 kg nitrogen/fed as urea) under the same planting date December 9th in the two seasons. Similarly, Pavlou *et al.* (2007) on lettuce revealed that following the three crop seasons (late spring, late autumn and late winter) the residual availability of N, P and K was clearly enhanced in the soil receiving the organic compared to the inorganic fertilization.

Essential oil%, essential oil yield (g/plant) and essential oil yield (l/fed)

From the data presented in Table 9 it could be concluded that planting dates significantly affected on essential oil%, essential oil yield/plant and /fed in the both seasons. The third sowing date at December 9th gave the highest essential oil%, essential oil yield/plant and /fed in the both seasons. These results may be due to the fact that date of sowing is an important management factor for almost all seed spices including coriander. Change in sowing time leads to significant change in weather microclimate (Figs. 1 and 2) and subsequently the performance of the crop. In addition, the physical environment has profound influence on growth, biomass partitioning and ultimately the yield of coriander. Temperature, humidity, rainfall and other meteorological factors may individually or collectively limit the plant growth and production. Time of sowing controls the crop phonological development along with efficient conversion of biomass into economic yield (Khichar

Table 9 Effect of planting date, mineral and organic nitrogen fertilization on essential oil%, essential oil yield (ml/plant) and essential oil yield (l/fed) of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

Planting date	Fertilization treatments	Essential oil%		Essential oil yield (ml/plant)		Essential oil yield (l/fed)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10th October	F_1	0.29	0.30	0.19	0.24	3.92	4.78
	F_2	0.24	0.24	0.13	0.16	2.59	3.17
	F_3	0.26	0.29	0.20	0.24	4.01	4.73
	F_4	0.30	0.35	0.22	0.28	4.33	5.58
9th November	F_1	0.21	0.22	0.12	0.16	2.44	3.27
	F_2	0.22	0.26	0.18	0.24	3.75	4.73
	F_3	0.35	0.35	0.34	0.33	6.92	6.71
	F_4	0.31	0.33	0.28	0.34	5.75	6.85
9th December	F_1	0.25	0.26	0.15	0.18	3.12	3.63
	F_2	0.38	0.35	0.33	0.34	6.79	6.86
	F_3	0.33	0.33	0.29	0.31	5.83	6.19
	F_4	0.33	0.34	0.35	0.37	6.99	7.38
$LSD_{0.05}$		0.018^{***}	0.019^{***}	0.042^{***}	0.051^{***}	0.865^{***}	1.014^{***}
Planting date	10 Oct.	0.27	0.29	0.18	0.23	3.71	4.57
	9 Nov.	0.28	0.29	0.22	0.30	4.71	5.39
	9 Dec.	0.33	0.32	0.28	0.27	5.68	6.02
$LSD_{0.05}$		0.023^{**}	0.014^{*}	0.032^{**}	0.15^{***}	0.616^{***}	0.296^{**}
Fertilization treatment	F_1	0.25	0.26	0.15	0.19	3.16	3.90
	F_2	0.28	0.29	0.22	0.24	4.37	4.92
	F_3	0.32	0.33	0.28	0.29	5.59	5.89
	F_4	0.32	0.34	0.29	0.33	5.69	6.61
$LSD_{0.05}$		0.012^{***}	0.013^{***}	0.016^{***}	0.025^{***}	0.340^{***}	0.521^{***}

*, **, *** and NS: significant at $p \leqslant 0.05$, 0.01, 0.001 or not significant, respectively. Means separated at $p \leqslant 0.05$, LSD test.
F_1: without nitrogen fertilization, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea (46.5% N) + 30 kg N as compost/fed, F_4: 60 kg nitrogen/fed as urea (46.5% N).

and Niwas, 2006). The effect of sowing date on essential oil percentage of various aromatic and medicinal plants was studied by several authors i.e. Naguib *et al.* (2007) on *R. graveolens* L. who showed that the second sowing date at 1st November gave the highest essential oil%. Muni *et al.* (2001) found that oil yield of four cultivars of *Mentha arvensis* was generally decreased with the delay in planting from January 20th to February 20th. Hadj Seyed Hadi *et al.* (2004) on chamomile found a decreasing trend in essential oil concentration by the delay in spring planting.

Application coriander with nitrogen fertilization significantly affected essential oil%, essential oil yield/plant and /fed comparing with control. The significantly high values of all oil parameters were recorded from F_4: 60 kg nitrogen/fed as urea. These results may be attributed to the role of nitrogen in increasing many energy-rich compounds that regulate photosynthesis and plant production. Rastgou *et al.* (2013) on safflower found that the oil content of seeds generally increases with the increase of nitrogen level consumption. Furthermore, considering oil content of seeds there were no significant differences between 150 and 200 kg N ha^{-1} (increased more than 40%).

Regarding the interaction effect between planting dates and N fertilization treatments data showed that plants fertilized with F_2 (30 kg nitrogen/fed as urea + 30 kg N as compost/fed) sowing on December 9th gave the maximum essential oil %, while, plants fertilized F_4: 60 kg nitrogen/fed as urea on the same time gave the highest essential oil yield/plant and essential oil yield/fed in both the seasons.

Relationship between planting date and nitrogen fertilization with essential oil%, essential oil yield (ml/plant) and essential oil yield (l/fed)

A positive linear relationship was obtained between planting date with essential oil%, essential oil yield/plant and /fed (Fig. 5). They are highly significant (with correlation coefficient values, r = 0.75, 0.32 and 0.99 respectively for the first season and 0.87, 0.98 and 0.99, respectively for the second season). The positive relationship indicated that each of essential oil%, essential oil yield/plant and /fed increased under the last planting date December 9th. Similarly, a positive linear relationship was obtained between nitrogen fertilization with essential oil%, essential oil yield/plant and /fed (Fig. 5). They are highly significant (with correlation coefficient values, r = 0.95, 0.99 and 0.99 respectively for the first season and 0.89, 0.92 and 0.91 respectively for the second season). The positive relationship indicated that each of essential oil%, essential oil yield/plant and /fed increased with the use of F_4: 60 kg nitrogen/fed as urea.

Essential oil constituents

Data presented in Table 10 revealed that fourteen components were identified in coriander oil as α-pinene, myrcene,

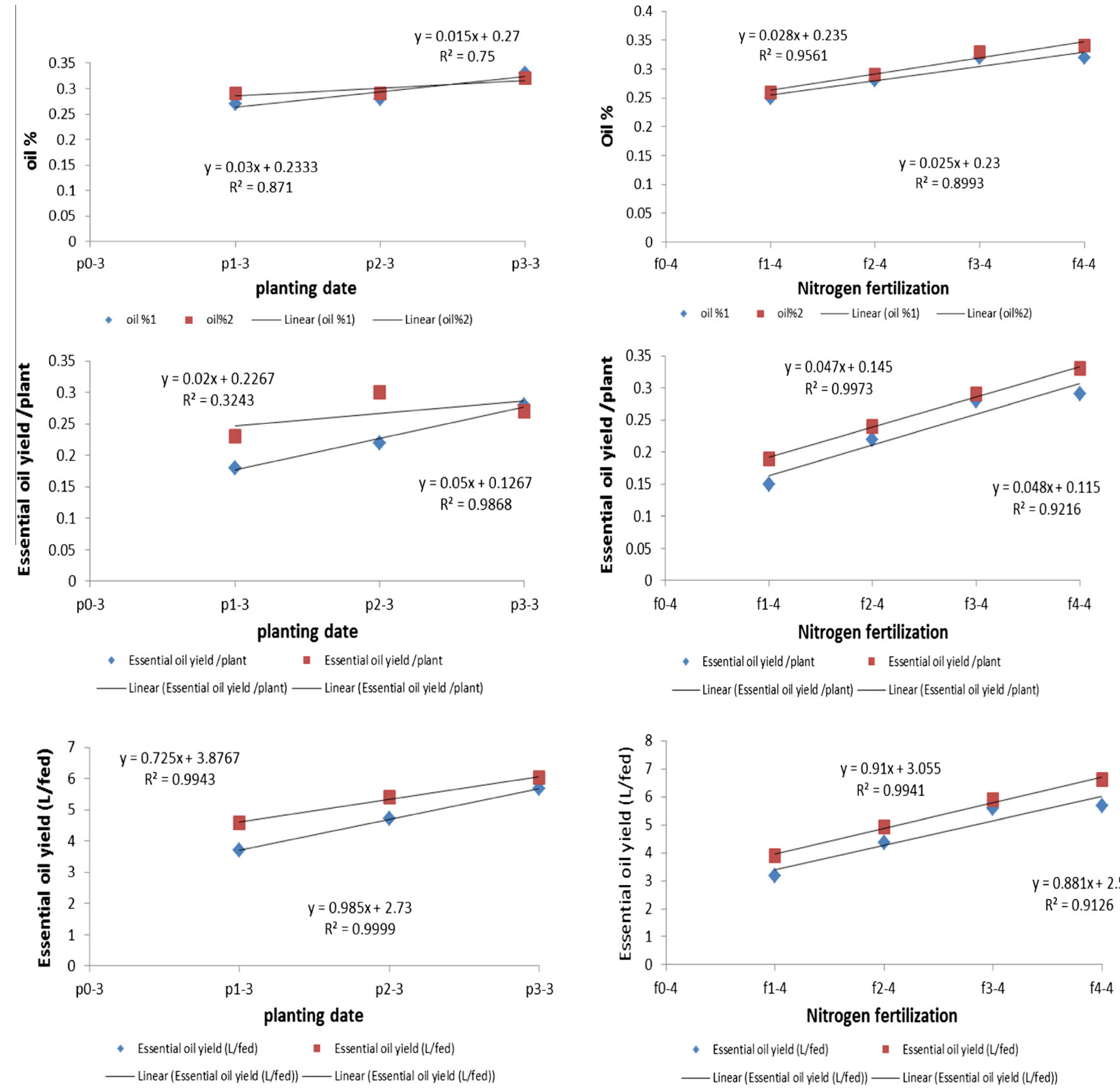

Fig. 5 Correlation between planting date and mineral and organic nitrogen fertilization on Essential oil%, essential oil yield (ml/plant) and essential oil yield (l/fed) of *Coriandrum sativum*, L. during the two seasons (2013 and 2014).

camphene, β-pinene, p-cymene, limonene, borneol, linalool, nerol, menthone, geraniol, eugenol, geranyl acetate and terpinene-4-ol. Linalool was found to be the first major compound. The highest percentage of linalool was obtained from oil sample from plants sowing on December 9th and fertilized with F_4 (60 kg nitrogen/fed as urea) (77.31%), while the lowest one was in case of plants sown in October 10th and fertilized with F_3: 60 kg nitrogen/fed as urea (46.5% N). The highest percentages are as follows: α-pinene (3.4%), myrcene (3.54%), camphene (3.41%), β-pinene (5.41%), p-cymene (2.8%), borneol (2.78%), nerol (2.50%), geraniol (4.4%) geranyl acetate (2.8%) and terpinene-4-ol (2.2%), eugenol (4.5%), limonene (3.77%) and menthone (4.9%). The change in the components quality occurred by using mineral and organic nitrogen fertilization under different planting time may be due to their role on the metabolism and on the enzyme responsible for the components synthesis. Similarly, Hesham and Ghaly (2003) found that notrobein and phosphorein plus mineral fertilization affected the composition of *C. sativum*, L. as, linalool was the major constituent forming more than 76% of the oil and the other constituents were α-pinene, camphene, β-pinene, limonene, menthone, geraniol and eugenol. Also, Rashed *et al.* (2011) on *Achillea millefolium*, L.

Conclusion

The practical conclusion to be drawn from the experiment is that, on the basis of the data, it should be possible to produce coriander fruits of more than adequate quality in Kafr El-Sheikh Governorate when cultivate coriander at the first third of December under the studied region and fertilizing plants with 60 kg nitrogen/fed as urea. However, the highest yield was achieved with the highest benefit from the soil, the days to harvest decreased to 129 days, this time of planting saves about two months for planting any short crop which increases economic values of soil and the highest essential oil%, essential oil yield/plant and /fed and saves water applied.

Table 10 Effect of planting date, mineral and organic nitrogen fertilization on essential oil constituents % of *Coriandrum sativum*, L. during the second season of 2013 and 2014.

Components	Treatment											
	10th October				9th November				9th December			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
α-pinene	3.4	1.1	3.20	2.8	1.5	2.20	1.6	1.2	2.3	0.57	2.23	1
myrcene	2.0	1.2	3.54	2.0	3.00	3.54	1.2	2.2	2.2	1.2	1.54	2
camphene	1.9	3.41	1.20	1.6	2.09	1.00	1.3	0.29	1.03	1.02	2.11	1.05
β-pinene	4.1	2.2	2.15	2.5	0.88	2.15	1.6	0.20	2	3	5.41	0.03
p-cymene	1.2	1.0	1.57	1.5	1.5	1.58	0.8	1.0	2.8	2.2	2.12	1.5
limonene	2.8	0.42	0.5	2.0	3.57	1.0	1.4	3	3.77	0.66	1.2	0.14
borneol	1.8	1.6	2.78	2.5	2.5	2.53	1.2	1.6	1.1	1.0	2.00	2.5
linalool	65.1	65.8	60.00	68.0	65.36	64.45	70.0	72.44	72.24	76.47	63.46	77.31
nerol	1.5	1.1	2.11	1.7	1.6	2.50	1.6	2.1	1.0	2.00	2.40	2.1
menthone	4.0	1.02	0.5	4.2	4.90	1.5	2.0	3.5	2	1.2	1.8	1.14
geraniol	2.9	4.4	2.17	2.4	1.72	1.51	2.1	1.14	2	1.3	1.11	3.96
eugenol	3.1	4.5	1.00	3.7	2.71	0.5	1.0	1.64	2.6	1.6	1.3	1.64
geranyl acetate	2.8	1.8	1.48	1.8	1.5	1.45	1	1.8	1.8	1.8	1.11	1.8
terpinene-4-ol	2.2	2.2	1.52	2.2	1.5	1.18	1	2.2	1.2	2.2	1.30	2.2
Total identified	98.8	91.75	83.72	98.9	94.33	87.09	87.8	94.31	98.04	96.22	89.09	98.37
Unidentified compound	1.2	8.25	14.34	1.1	5.67	21.91	1.2	5.69	1.96	3.78	10.91	1.63

F_1: without nitrogen fertilization, F_2: 60 kg nitrogen/fed as compost, F_3: 30 kg nitrogen/fed as urea (46.5% N) + 30 kg N as compost/fed, F_4: 60 kg nitrogen/fed as urea.

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